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insect is now abundant in Washington, it will scarcely be noticed in any part of the District seventeen years hence. I base this opinion upon a new phase in the cicada history; viz., the presence of the English sparrow. It is the first time, perhaps, in the history of the world, that *Passer domesticus* has had an opportunity of feeding upon this particular brood of Cicada septendecim: and so ravenously and persistently does this bird pursue its food, that the ground is strewn with the wings of the unfortunate cicada wherever these have been at all numerous; so that, considering the numbers of the sparrow and their voracity, very few of the cicada will be left long enough to procreate and perpetuate the species in this District.

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THE GEOLOGY OF NATURAL GAS.

THE recent introduction of natural gas into general use as a source of heat for industrial and domestic purposes has raised it from the rank of a mere curiosity to one of the earth's most valuable treasures.

To the reader unacquainted with the great change natural gas has effected in all industries where it can be obtained, the following quotation from an article in *Macmillan's magazine* for January, written by Mr. Andrew Carnegie, the chief iron master of Pittsburgh, will be a revelation: "In the manufacture of glass, of which there is an immense quantity made in Pittsburgh, I am informed that gas is worth much more than the cost of coal and its handling, because it improves the quality of the product. One firm in Pittsburgh is already making plate glass of the largest sizes, equal to the best imported French glass, and is enabled to do so by this fuel. In the manufacture of iron, and especially in that of steel, the quality is also improved by the pure new fuel. In our steel-rail mills we have not used a pound of coal for more than a year, nor in our iron mills for nearly the same period. The change is a startling one. Where we formerly had ninety firemen at work in one boiler-house, and were using four hundred tons of coal per day, a visitor now walks along the long row of boilers, and sees but one man in attendance. The house being whitewashed, not a sign of the dirty fuel of former days is to be seen; nor do the stacks emit smoke. In the Union iron-mills our puddlers have whitewashed the coal-bunkers belonging to their furnaces. Most of the principal iron and glass establishments in the city are to-day either using this gas as fuel, or making preparations to do so. The cost

of coal is not only saved, but the great cost of firing and handling it; while the repairs to boilers and grate-bars are much less."

This new fuel, which bids fair to replace coal almost entirely in many of our chief industrial centres, has not received that attention from the geologist which its importance demands. So far as the writer is aware, nothing has been published on the subject which would prove of any value to those engaged in prospecting for natural gas, and it is the existence of this blank in geological literature that has suggested the present article.

Practically all the large gas-wells struck before 1882 were accidentally discovered in boring for oil; but, when the great value of natural gas as fuel became generally recognized, an eager search began for it at Pittsburgh, Wheeling, and many other manufacturing centres.

The first explorers assumed that gas could be obtained at one point as well as another, provided the earth be penetrated to a depth sufficiently great; and it has required the expenditure of several hundred thousand dollars in useless drilling to convince capitalists of this fallacy which even yet obtains general credence among those not interested in successful gas companies.

The writer's study of this subject began in June, 1883, when he was employed by Pittsburgh parties to make a general investigation of the natural-gas question, with the special object of determining whether or not it was possible to predict the presence or absence of gas from geological structure. In the prosecution of this work, I was aided by a suggestion from Mr. William A. Earsenian of Allegheny, Penn., an oil-operator of many years' experience, who had noticed that the principal gas-wells then known in western Pennsylvania were situated close to where anticlinal axes were drawn on the geological maps. From this he inferred there must be some connection between the gas-wells and the anticlines. After visiting all the great gas-wells that had been struck in western Pennsylvania and West Virginia, and carefully examining the geological surroundings of each, I found that every one of them was situated either directly on, or near, the crown of an anticlinal axis, while wells that had been bored in the synclines on either side furnished little or no gas, but in many cases large quantities of salt water. Further observation showed that the gas-wells were confined to a narrow belt, only one-fourth to one mile wide, along the crests of the anticlinal folds. These facts seemed to connect gas territory

unmistakably with the disturbance in the rocks caused by their upheaval into arches, but the crucial test was yet to be made in the actual location of good gas territory on this theory. During the last two years, I have submitted it to all manner of tests, both in locating and condemning gas territory, and the general result has been to confirm the anticlinal theory beyond a reasonable doubt.

But while we can state with confidence that all great gas-wells are found on the anticlinal axes, the converse of this is not true; viz., that great gas-wells may be found on all anticlinals. In a theory of this kind the limitations become quite as important as, or even more so than, the theory itself; and hence I have given considerable thought to this side of the question, having formulated them into three or four general rules (which include practically all the limitations known to me, up to the present time, that should be placed on the statement that large gas-wells may be obtained on anticlinal folds), as follows:—

(a) The arch in the rocks must be one of considerable magnitude; (b) A coarse or porous sandstone of considerable thickness, or, if a fine-grained rock, one that would have extensive fissures, and thus in either case rendered capable of acting as a reservoir for the gas, must underlie the surface at a depth of several hundred feet (five hundred to twenty-five hundred feet); (c) Probably very few or none of the grand arches along mountain ranges will be found holding gas in large quantity, since in such cases the disturbance of the stratification has been so profound that all the natural gas generated in the past would long ago have escaped into the air through fissures that traverse all the beds. Another limitation might possibly be added, which would confine the area where great gas-flows may be obtained to those underlaid by a considerable thickness of bituminous shale.

Very fair gas-wells may also be obtained for a considerable distance down the slope from the crest of the anticlinals, provided the dip be sufficiently rapid, and especially if it be irregular, or interrupted with slight crumples. And even in regions where there are no well-marked anticlinals, if the dip be somewhat rapid and irregular, rather large gas-wells may occasionally be found, if all other conditions are favorable.

The reason why natural gas should collect under the arches of the rocks is sufficiently plain, from a consideration of its volatile nature. Then, too, the extensive fissuring of the rock, which appears necessary to form a

capacious reservoir for a large gas-well, would take place most readily along the anticlinals where the tension in bending would be greatest.

The geological horizon that furnishes the best gas-reservoir in western Pennsylvania seems to be identical with the first Venango oil-sand, and hence is one of the Catskill conglomerates. This is the gas-rock at Murrysburg, Tarentum, Washington, Wellsburg, and many other points. Some large gas-wells have been obtained in the subcarboniferous sandstone (Poccono), however, and others down in the third Venango oil-sand (Chemung).

In Ohio, gas-flows of considerable size have been obtained deep down in the Cincinnati limestone, while in West Virginia they have been found in the Pottsville conglomerate: hence natural gas, like oil, has a wide range through the geological column, though it is a significant fact that it is most abundant above the black slates of the Devonian.

Of the composition, probable origin, extent of gas territory in the country, and many other interesting points connected with natural gas, the necessary brevity of this article forbids any mention; but the writer has in preparation a more general paper on the subject, in which these and kindred questions will be discussed with more detail.

I. C. WHITE.

THE EFFECTS OF COLD ON LIVING ORGANISMS.

MR. COLEMAN and Professor McKendrick have made some remarkable experiments¹ on the effect of low temperatures on living organisms, particularly microbes, using for this purpose the cold-air machinery invented by Mr. Coleman, which, in its ordinary working, delivers streams of air cooled to about 80° below zero (— 63° C.), but by certain modifications as low temperatures can be secured as have yet been produced in physical researches. The actual temperatures in these experiments were taken by an absolute alcohol thermometer, made by Negretti and Zambra, and checked by a special air thermometer devised by Mr. Coleman.

The experiments consisted in exposing for hours to low temperatures putrescible substances in hermetically sealed tins or bottles, or in flasks plugged with cotton wool. The tins or flasks were then allowed to thaw, and were kept in a warm room, the mean temperature of which was about 80° F. They were then opened, and the contents submitted to microscopical examination. The general result may be stated thus: The vitality of micro-organisms cannot be destroyed by prolonged exposure to extreme cold. It is clear, therefore, that any hope of preserving meat by permanently sterilizing it by cold must be

¹ Proc. Philos. soc. Glasgow, March 4, 1885.